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Capturing the economic benefit of *Lolium perenne* cultivar performance

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Economic values were calculated for grass traits of economic importance in Irish grass-based ruminant production systems. Traits considered were those that had the greatest potential to influence the profitability of a grazing system. These were: grass dry matter (DM) yield in spring, mid-season and autumn, grass quality (dry matter digestibility; DMD), 1st and 2nd cut silage DM yield and sward persistency. The Moorepark Dairy Systems Model was used to simulate a dairy farm. Economic values were calculated by simulating the effect of a unit change in the trait of interest while holding all other traits constant. The base scenario involved a fixed herd size and land area (40 ha), and an annual DM yield of 13 t/ha. The economic values generated under the base scenario were: €0.152/kg for DM yield in spring, €0.030/kg for DM yield in mid-season and €0.103/kg for DM yield in autumn; €0.001, €0.008, €0.010, €0.009, €0.008 and €0.006 per 1 g/kg change in DMD for the months of April to September, respectively; €0.03/kg for 1st cut silage DM yield, €0.02/kg for 2nd cut silage DM yield; and −€4.961 for a 1 percent reduction in persistency. Alternative scenarios were examined to determine the sensitivity of the economic values to changes in annual DM yield, sward utilisation and a scenario where silage production was the focus of the system. The economic values were used to calculate a total merit index for each of 20 perennial ryegrass cultivars based on production data from a 3 year plot study. The rank correlation between the merit index values for the cultivars under the base scenario and the scenario involving a reduction in herbage utilisation was 1.0, while that with the scenario involving reduced annual DM yield was 0.94. It is concluded that the total merit index can be used to identify cultivars that can generate the greatest economic contribution to a grass-based production system, regardless of system or intensity of grass production.

Keywords: economic value; herbage yield; perennial ryegrass; quality

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Introduction

Perennial ryegrass (*Lolium perenne* L.) is one of the most important forage species for ruminant animal production in temperate regions. Eighty percent of the world's bovine milk and 70% of the world's beef and veal are produced from temperate grassland systems (Wilkins and Humphreys 2003). Recent increases in production costs and lower product prices, as well as the perceived environmental and animal welfare concerns associated with intensive indoor production systems (Dillon *et al*. 2005), have rejuvenated interest in grazing systems in many temperate and sub-tropical regions of the world (especially Europe and the USA). Gains through forage breeding, in terms of dry matter (DM) yield for the important species, of 4 to 5% per decade have been achieved over the last 50 years, while improvements of 10 g/kg have been achieved per decade in dry matter digestibility (DMD) of perennial ryegrass (Wilkins and Humphreys 2003). The improvement in animal performance as a result of this increase in DMD is not clearly defined, as differences in DM production and quality between cultivars can be exaggerated by factors such as climate, soil and farming system (DAFF 2009). Genotype × environment (G × E) interactions, which include the effects of management and year, are observed widely in the evaluation of perennial ryegrass cultivars (Jafari, Connolly and Walsh 2003). Such interactions indicate changes in the rank order of genotypes, the magnitude of differences among genotypes, or both, between different environments (Conaghan *et al*. 2008).

Many countries independently evaluate grass cultivars to identify those that are most suitable for local growing conditions through Recommended Lists. Dry matter yield is the most commonly reported trait in these trials. Other traits that may be reported include heading date, seasonal yield, sward quality, persistency, winter hardiness and disease resistance. The significance of a Recommended List is its potential to influence the market, thereby resulting in the rapid uptake of new cultivars (Bentley 2003).

In animal selection, Beard (1987) reported that genetic progress could be maximized in economic terms if selection was for an index that comprised the sum of the breeding values for traits of economic importance weighted according to their relative economic values. In cattle breeding, the development of a total merit index to assist farmers in identifying the most profitable bulls for breeding (Veerkamp *et al*. 2002) has been successfully adopted in many countries, including New Zealand (Breeding Worth; NZAEL 2009), USA (AIPL 2010), Canada (CDN 2010) and the Republic of Ireland (Economic Breeding Index; ICBF 2008). The development of a similar approach to rank grass cultivars would be a significant advancement in the identification of cultivars that can deliver the highest increases in profitability at farm level. A number of studies were reviewed (Dillon *et al*. 1995; Drennan and McGee 2009; Keady, Hanrahan and Flanagan 2009) to identify the most valuable traits affecting grass-based production systems and the findings are similar to those reported by others (Casler 2000; DAFF 2009; Wilkins and Humphreys 2003). The important traits for a grass economic merit index were identified as those that have the largest effect on the economic performance of a system. Additionally, it was considered of critical importance that the traits selected be easily measured and improvement in each trait must be achievable through plant breeding, and hence breeders can apply a weighting within their breeding programmes to each trait as appropriate.

The first objective of this study was to describe an economic index for perennial ryegrass cultivars; the second objective was to evaluate the performance of 20 cultivars under three different management protocols; the final objective was to apply the economic values to the performance of these cultivars.

Materials and Methods

The Moorepark Dairy Systems Model (MDSM) provides a comprehensive simulation framework integrating biological, physical and economic processes for a dairy farm (Shalloo *et al*. 2004). The MDSM incorporates herd parameters, nutritional requirements, land use and total inputs and outputs across the calendar year. The major revenues in the MDSM are milk and livestock sales. Land area is treated as an opportunity cost; all land was rented as required for on-farm feeding of animals. Variable costs (fertilizer, concentrate, veterinary, medicine, artificial insemination, silage making, reseeding and contractor charges), fixed costs (car, electricity, labour, machinery operation and repair, phone, insurance, etc.) and receipts (sales of livestock, milk and calves) were based on current prices (Teagasc 2008). The levels of feed offered were determined by the energy requirements of the animals for maintenance, milk production and body weight change (Jarrige 1989). This information was used to generate the base scenario for the model dairy farm.

The key assumptions used in the MDSM are shown in Table 1. The gross milk price received was based on Binfield *et al*. (2008). A total annual grass DM production of 13 t/ha was assumed. The base scenario involved 40 ha of land stocked at 1.9 cows/ha. Cow numbers were fixed to isolate the herbage effects from the animal effects within the model. A fixed land area was used to represent a typical Irish farming system. Calving began in spring and cows were turned out to grass immediately post-calving. Mean calving date was 24 February, with a calving interval of 365 days; 70%, 20% and 10% of the cows calved in February, March and April, respectively. The feed budget reflected the calving pattern. A key objective was to maximise the proportion of grass in the diet, while meeting the energy requirements of the system. The MDSM was used to simulate a model farm, while integrating, in turn, the effect of a change in each trait of importance for a grass-based ruminant production system.

Table 1. Base parameters used for variables in the Moorepark Dairy Systems Model (Shalloo *et al.* 2004)

Variable	Default value
Farm size (ha)	40
Stocking rate (cows/ha)	1.9
Gross milk price (€/L)	0.27
Fat price (€/kg)	3.13
Protein price (€/kg)	6.27
Opportunity cost of land (€/ha)	297
Concentrate cost (€/t)	220
Fertilizer cost[a] (€/ha)	325
Livestock sales	36 978
1st Cut silage contracting (€/ha)	284
2nd Cut silage contracting (€/ha)	235
Reseeding cost (€/ha)	496

[a] Includes calcium ammonium nitrate, urea and compound fertilizer containing N, P and K.

Trait definition and methodology to calculate economic value

To derive each economic value a physical change (Δ) was independently simulated for each trait of interest. The effect (Δ) that changing a trait had on the net margin of the system (€/ha) compared to that for the base scenario was used to determine the economic value of the trait (Veerkamp *et al*. 2002).

The economic value of a trait can be described as follows:

$$Economic\ value = \frac{\Delta\ net\ margin\ per\ hectare}{\Delta\ in\ trait\ of\ interest}$$

The traits of importance for grass based systems were identified as follows:

Dry matter yield: An economic value was calculated for spring, mid-season and autumn DM yields. In spring and autumn the economic value was based on the assumption that each additional 1 kg of grass DM consumed would displace silage or concentrate on an equal energy basis. The economic value for mid-season DM yield was calculated on the assumption that each additional 1 kg of grass DM produced would allow an increase in the carrying capacity of the farm, therefore allowing a higher stocking rate (SR) to be maintained. The economic values presented for DM yield account for differences in the utilisation of herbage as the season advances. Utilisation refers to the proportion of the grown herbage that is consumed by the animal. It was assumed that herbage DM utilisation under grazing for spring, mid-season and autumn was 90%, 85% and 80%, respectively (O'Donovan and Kennedy 2007). The utilisation of the herbage was determined above 4 cm as this is what is considered to be available to the grazing animal.

Dry matter digestibility: The French Fill Unit system is used within the MDSM to determine the energy requirements of the system. The following equation is used to determine the intake capacity (IC) of a lactating dairy cow using the equation of Faverdin *et al*. (2007):

$$IC = [13.9 + (0.015(BW - 600)) + (0.15 \times MY_{Pot}) + (1.5 \times (3 - BCS))] \times IL \times IP \times IM,$$

where BW = body weight, MY_{Pot} = potential milk yield, BCS = body condition score, IL = index of lactation $\{= a + (1 - a)(1 - e^{-0.16\ \text{lactation week}})$, where a is 0.6 for primiparous, 0.7 for multiparous cows and 1 for dry cows$\}$, IP = index of pregnancy $\{= 0.8 + 0.2(1 - e^{-0.25\ (40-\ \text{pregnancy week})})\}$, IM = index of maturity $\{= -0.1 + 1.1 (1 - e^{-0.08\ \text{age in months}})\}$.

The fill unit system separately predicts IC of an animal and the fill value of the feed (FV), both expressed in fill units (Jarrige 1989). If a forage is offered *ad libitum* as the sole feed, the voluntary dry matter intake of that forage is obtained by dividing IC of the animal by the forage FV (Jarrige 1989). The IC is a function of animal characteristic, and forage FV is a function of the forage characteristics (including chemical composition). In the MDSM the feed intake required is adjusted to meet the net energy requirements of the animal, and therefore feed intake is adjusted as herbage quality changes. When the DMD of the sward declines, FV increases and consequently there is a requirement for increased intake to meet energy demand. If the necessary increase is sufficiently large the intake required to meet animal energy requirements will exceed IC; under these conditions milk production is reduced. For each month from April to September, inclusive, the economic value of a proportional reduction of 0.01 in herbage DMD was calculated. In April, simulating a reduction in the quality of the herbage offered did not result in a required herbage intake that exceeded IC. However, simulating a reduction in DMD of the sward in the May to September period, resulted in the animal being unable to meet energy requirements as the required herbage intake exceeded IC and, hence, milk production in the system was reduced.

Silage yield: Within Irish grass-based production systems there are generally two silage harvests. As a result two economic values are required for silage; one for the 1st cut and one for the 2nd cut. Total yields for 1st and 2nd cut were calculated on the assumption that 80% of the DM harvested was utilised, to account for losses during harvesting, conservation, ensiling and feeding (Forristal, O'Kiely and Lenehan 1995; P. O'Kiely 2010, personal communication).

Persistency: The economic value for persistency was derived by assuming a sward longevity of 10 years, based on current guidelines. The economic value for persistency was calculated based on a proportional change of 0.01 in the lifetime of the sward relative to the base of 10 years. The economic value for persistency was calculated based on the current estimates of the cost of reseeding.

Alternative scenarios

Alternative scenarios were also simulated to examine the robustness of cultivar ranking across a range of farming intensities and systems of production. The scenarios examined were:

- S1 herbage DM utilisation reduced to 80% (spring), 75% (mid-season) and 70% (autumn); this represents a medium utilisation of herbage
- S2 herbage DM utilisation reduced to 75% (spring), 70% (mid-season) and 65% (autumn); this represents low utilisation of herbage
- S3 herbage DM production of 11 t/ha, representing a low production of herbage
- S4 In this scenario silage yield was the only trait of importance. This would apply where a specific area of the farm is designated for silage harvesting, generally separate from the main grazing area.

Cultivar performance study

A plot study was carried out at Moorepark (50°07N′ 8°16′W) to determine the effect of management protocol on cultivar performance. The soil type was a free-draining, acid brown earth soil with a sandy-loam texture. Twenty cultivars of perennial ryegrass were sown in August 2006 in a randomized complete block design, involving 180 plots (each 1.5 m × 5 m). The plots were evaluated for 3 consecutive years: 2007, 2008 and 2009. Three managements were applied to assess the effect of evaluation protocol on cultivar performance and economic ranking. Each management was replicated three times. Management 1 (RG) represented a rotational simulated-grazing system, incorporating 10 harvests during the March to November period. A total of 385 kg/ha N was applied annually. Management 2 (2C) incorporated a 2-cut silage system, with the first cut in April, representing simulated grazing, followed by two silage harvests (in May and late June) and 3 subsequent harvests, representing simulated grazing, the last of which was taken in October. The third management (3C) incorporated a 3-cut silage system with three silage harvests (in late May, early July and mid-August) followed by 2 simulated grazings. There was no simulated grazing harvest in spring in the 3C management. The annual fertilizer N application to both managements 2C and 3C was 350 kg/ha. Nitrogen was applied in the form of calcium ammonia nitrate within 2 days of cutting. No fertilizer N was applied after the final harvest in any year. In November 2006 all plots were harvested to a post-cutting height of 4 cm. Dry matter yield was determined each year and sward quality was measured for 2 years (2007 and 2008) on all harvests. The harvest dates (± 3 days) and N fertilizer inputs following each harvest are given in Table 2.

Dry matter yield was measured on each plot at each cut. The full length of the plot was harvested (cutting width 1.2 m), using a mechanical mower (Etesia, UK Ltd, Warwick, UK), to a height of 4 cm. All mown herbage from each plot was collected,

Table 2. Cutting intervals and fertilizer N inputs for the three cutting management systems

Event	Simulated grazing		2-Cut silage		3-Cut silage	
	Date	N (kg/ha)	Date	N (kg/ha)	Date	N (kg/ha)
Fertilizer[a]	20 February	70	20 February	40	20 March	100
Cut 1[b]	20 March	35	30 March	100	22 May	90
Cut 2	+3 weeks	35	+7 weeks[c]	90	+6 weeks[c]	90
Cut 3	+3 weeks	35	+6 weeks[c]	50	+6 weeks[c]	35
Cut 4	+3 weeks	35	+4 weeks	40	+5 weeks[c]	35
Cut 5	+3 weeks	35	+5 weeks	30	+4 weeks	
Cut 6	+3 weeks	35	+6 weeks			
Cut 7	+4 weeks	35				
Cut 8	+4 weeks	35				
Cut 9	+4 weeks	35				
Cut 10	+4 weeks					

[a] Indicates fertilizer application only. All other fertilizer applications occurred after harvesting.
[b] First harvest.
[c] Indicates silage harvest.

weighed and subsampled (0.1 kg). The subsample was oven dried for 48 h at 40 °C to determine DM yield. In 2007 and 2008, the dried sample was milled through a 1 mm screen for the determination of DMD using Near Infrared Spectroscopy (NIRS).

Data were analyzed using analysis of variance (SAS 2006). Replicate was considered as a random effect. Year, management, cultivar and their interactions were included in the model.

Application of economic values to production data

The cuts in the simulated grazing management system were classified into seasonal periods as follows: spring (autumn closing until 10 April), mid-season (11 April to 6 August) and autumn (7 August until final harvest). In order to apply the economic values to the biological data to determine the economic merit of a cultivar, the values for DM yield in spring, mid-season and autumn and the monthly quality values from the RG protocol were used. The data from the 1st and 2nd silage harvests of the 2C protocol were used to determine the economic value of silage for each cultivar. Additionally, the 1st and 2nd cut silage DM yield recorded for the 3C protocol was used to assess the economic merit within the silage only scenario (S4).

Within each scenario, the average performance of the 20 cultivars for a trait was subtracted from the actual performance of an individual cultivar. This difference was then multiplied by the economic value for the trait to generate the economic value for each trait for each cultivar. The sum of the economic values across traits (yield, quality, silage and persistency) was then used to calculate the total economic merit of a cultivar. Spearman's rank correlation was used to examine the degree of re-ranking of cultivars when the economic values from the different scenarios were applied to the production data.

Results

Farm performance under base scenario

Details on the herd parameters from January to December (365 days) for the base scenario are presented in Table 3. Total annual intake per cow was 3947,

Table 3. System performance under base scenario over a calendar year

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Animals present												
Total cows	71	80	82	82	81	79	78	77	77	76	75	74
Cows in milk	22	66	75	82	81	79	78	77	77	76	75	74
Cows dry	49	14	7	–	–	–	–	–	–	–	–	–
Cows calved	–	59	17	8	–	–	–	–	–	–	–	–
Replacements calved	–	12	3	2	–	–	–	–	–	–	–	–
Milk output												
Milk production (% of annual total)	0.99	3.59	10.86	13.08	13.84	12.11	11.13	9.90	8.38	6.99	5.69	3.44
Fat concentration (g/kg)	44.3	39.6	36.8	35.0	34.4	34.7	35.6	36.9	38.8	40.9	42.6	43.9
Protein concentration (g/kg)	37.3	31.5	31.2	31.8	32.4	32.7	32.9	33.7	35.3	36.7	37.4	37.8
Feed requirements per cow												
Grass DM[a] (kg/day)	0.0	2.3	7.6	11.9	16.3	17.3	17.3	16.4	15.6	13.7	10.7	0.1
Silage DM (kg/day)	10.9	7.4	3.6	0.5	–	–	–	–	–	–	1.4	13.0
Concentrate DM (kg/day)	0.3	2.1	4.2	2.9	0.2	–	–	–	–	1.0	1.0	0.5
Land use												
Area closed for silage (ha)	–	0.0	14.7	14.7	14.7	9.8	9.8	9.8	0.0	0.0	0.0	0.0
Area available for grazing (ha)	40.0	40.0	25.3	25.3	25.3	30.2	30.2	30.2	40.0	40.0	40.0	40.0
Area cut for silage (ha)	–	–	–	–	14.7	–	–	9.8	–	–	–	–
Utilisable herbage DM (kg/ha)	–	48.3	481.0	1393.3	1990.3	1741.6	1876.5	1587.0	1166.3	644.2	127.1	0.0

[a] DM = dry matter.

1114 and 366 kg DM as grazed grass, grass silage and concentrate, respectively; on a proportional basis these correspond to 0.71, 0.21 and 0.08 of the total diet, respectively. The proportions of grass, silage and concentrate in the diet are shown in Table 3 for each month. Total milk, fat and protein sales were 510 776 kg, 18 907 kg and 17 114 kg, respectively.

Economic values

The key system performance parameters for the default scenario and the changes that occur when a unit change in each trait was simulated are shown in Table 4. The calculated economic values for each trait are shown in Table 5.

Dry matter yield: An increase in spring DM yield resulted in an additional 43 kg grass DM available per cow in spring (Table 4), which displaced 26 kg silage DM and 24 kg concentrate DM per cow, while maintaining the energy requirements. This was equivalent to 82 kg/ha grass DM given that stocking rate was 1.9 cows/ha. Total costs were reduced compared to the base scenario and farm profit increased by €13.80/ha. This was corrected for spring DM utilisation; hence, the economic value for an increase in spring DM yield per hectare is €0.15/kg (Table 5). An increase in mid-season herbage production resulted in an extra DM production of 1.3 t/ha, of which 1.1 t/ha was utilized. The resultant increase in farm profit was €46.60/ha, or €0.03/kg DM when the utilisation was included. An increase in autumn DM yield resulted in an additional 47 kg/cow, which displaced 27 kg silage DM and 23 kg concentrate DM from the diet. This

Table 4. Key system performance components for the base scenario and following a unit change in each trait of interest

System component	Base scenario	Performance following change in											
		Grazing parameters										Silage parameters	
		Grazing DM yield[a] (kg/ha)			Dry matter digestibility[b] (g/kg)						Persistency[b]	Silage DM yield[a] (kg/ha)	
		Spring	Mid-season	Autumn	Apr	May	Jun	Jul	Aug	Sep		1st Cut	2nd Cut
Herbage yield (t/ha)	13.0	13.0	14.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Herbage DM[c] (kg/cow)	3947	3990	3947	3994	3977	3956	3949	3955	3957	3967	3947	3947	3947
Silage DM[c] (kg/cow)	1114	1088	1114	1087	1114	1114	1114	1114	1114	1114	1114	1114	1114
Concentrate DM[c] (kg/cow)	366	342	366	344	366	366	366	366	366	366	366	366	366
Farm size (ha)	40.0	40.1	37.2	40.1	40.2	40.0	40.0	40.0	40.1	40.1	40.0	39.4	39.7
Area used for silage (ha)	24.5	24.0	24.5	24.0	24.5	24.5	24.5	24.5	24.5	24.5	24.5	23.0	23.7
Silage yield 1st cut (kg/ha)	4435	4435	4435	4435	4435	4435	4435	4435	4435	4435	4435	4880	4435
Silage yield 2nd cut (kg/ha)	3558	3558	3558	3558	3558	3558	3558	3558	3558	3558	3558	3558	3914
Total milk sales (kg)	510 776	510 776	510 776	510 776	510 776	504 220	502 492	503 746	504 522	506 809	510 776	510 776	510 776
Milk returns (€)	142 847	142 847	142 847	142 847	142 847	141 120	140 641	140 941	141 090	141 667	142 847	142 847	142 847
Total costs (€)	152 692	152 136	150 828	152 226	152 843	152 729	152 690	152 719	152 727	152 778	152 912	151 902	152 257
Total profit (€)	27 134	27 690	28 998	27 600	26 982	25 369	24 929	25 201	25 342	25 868	26 914	27 924	27 569
Profit (€/ha)	678	692	725	690	674	634	623	630	633	646	673	698	689

[a] An increase in the trait was simulated to determine the effect on total performance of the system.
[b] A decrease in the trait was simulated to determine the effect on total performance of the system.
[c] Consumed per cow.

Table 5. Economic value (€/ha) per unit change in seasonal dry matter (DM) yield, herbage quality, silage DM yield and persistency

Trait	Unit change	Economic value (€/ha)
DM yield (kg/ha)		
Spring	1	0.15
Mid-season	1	0.03
Autumn	1	0.10
Herbage DM digestibility (g/kg)		
April	–1	–0.001
May	–1	–0.008
June	–1	–0.010
July	–1	–0.009
August	–1	–0.008
September	–1	–0.006
Silage DM yield (kg/ha)		
1st Cut	1	0.03
2nd Cut	1	0.02
Persistency	1 percentage point	–4.961

was equivalent to an increase of 89 kg/ha DM available in the autumn. The resultant increase in farm profit was € 11.60/ha, when corrected for the autumn utilisation rate this resulted in an economic value of € 0.10/kg DM.

Dry matter digestibility: A reduction of 1 g/kg in DMD had a negative effect on milk production across the months May to September, inclusive. In April, simulating a decrease in the DMD did not affect the energy intake of the animal, thus animal performance was unaffected, hence the resulting economic value for DMD change in April was small. During the months May to September, the FV of the grass restricted DMI and as a result milk yield declined. The resulting economic values for these months, per 1 g/kg reduction in DMD, were: –€ 0.008, –€ 0.010, –€ 0.009, –€ 0.008 and –€ 0.006, respectively.

Silage yield: An increase in silage DM yield meant that the total area required for both 1st and 2nd cut silage was reduced. Increased DM yield of 1st cut silage resulted in an additional 445 kg/ha DM conserved. The resulting total farm profit increased by € 9.70/ha. The economic value for each additional kilogram of DM conserved, assuming 80% utilisation, was € 0.03/ha. Increased DM yield for 2nd cut silage resulted in an additional 356 kg/ha DM conserved and an increase in farm profit of € 10.80/ha. Thus the economic value of each additional kilogram of DM was € 0.02/ha.

Persistency: A reduction of 1 percentage point in persistency per year resulted in a reduction of € 4.96/ha in farm profit.

Cultivar performance

The management system had a significant effect ($P<0.001$) on total DM yield of the 20 cultivars in the plot study. Average total DM yield under SG was 12.2 t/ha compared to 15.0 and 15.3 t/ha for the 2- and 3-cut silage systems, respectively. Cultivar significantly affected total DM yield ($P<0.001$), the highest DM yield was 14.6 t/ha (cultivar 14) and the lowest was 13.3 t/ha (cultivar 6). There was an interaction between management system and cultivar ($P<0.001$; Table 6).

The average DM production in spring, mid-season and autumn for the RG management system was 1704, 7106 and 3359 kg/ha, respectively. The average 1st and 2nd cut silage DM yields were 5175 and 3127 kg/ha for the 2C management, respectively, compared to 7089 and 3102 kg/ha for the 3C management, respectively. The economic value for each trait was applied to the production data for each management system as appropriate (Table 7) to determine the economic merit of each cultivar (Table 8). No persistency data were available on the 20 cultivars and so this trait was omitted from the calculation of the total merit index.

Scenario analysis

A comparison between the base scenario and S1 or S2 indicated that, despite the change in the economic merit of a cultivar

Table 6. Annual dry matter yield (kg/ha) of 20 cultivars under 3 different management systems

Cultivar	Management system		
	Simulated grazing[a]	2-Cut silage	3-Cut silage
1	12 758	14 841	14 766
2	12 549	14 763	14 916
3	12 238	14 876[b]	16 375[b]
4	12 507	15 881	15 674
5	13 012	14 955	15 427
6	11 200	14 496	14 373
7	12 158	14 571	15 172
8	12 363	16 072	15 353
9	12 103	15 252	15 025
10	12 174	15 786[b]	14 423[b]
11	12 029	15 357	15 504
12	11 983	15 463	15 741
13	11 796	15 517	15 873
14	11 918	15 411[b]	16 893[b]
15	11 757	14 651	14 373
16	12 564	13 878	14 583
17	11 937	15 374	15 643
18	11 719	14 641[b]	16 358[b]
19	11 843	14 271[b]	15 120[b]
20	12 805	14 855	15 358
Summary of statistical analysis:			
F test			
Year		***	
Management system		***	
Cultivar		***	
Management system × Cultivar		***	

[a] Yield in simulated grazing management was significantly different to that in 2-cut and 3-cut mangements for all cultivars.
[b] Indicates significant yield differences ($P<0.05$) between the 2-cut and 3-cut mangements.
The s.e. for management system × cultivar was 308.4.

when utilisation was reduced, there was no re-ranking of cultivars (r 1.0). Reducing total herbage DM production from 13 t/ha to 11 t/ha (S3), resulted in a change in the economic values; however, the rank correlation between the base scenario and S3 was high (0.94). In the case of S4 (silage only) the economic value for 1st and 2nd cut silage yield increased to € 0.093 and € 0.096 per 1 kg increase in DM yield, respectively. When the economic merit of a cultivar was calculated on the basis of silage yield only the correlation between the base scenario and S4 was very low (0.13).

Discussion

Improving the seasonal distribution of DM yield has long been a goal of forage breeders and agronomists through the extension of the growing season, either by early spring growth or late autumn growth, or more uniform production throughout the growing season (Casler and van Santen 2010). In the current study, a shift in the grass supply was simulated to increase the seasonal supply, while maintaining the same total annual DM production. The objective of this was to identify the benefit of increased seasonal DM production. In Ireland, there is a deficit of grass in the spring and late autumn periods, with surplus grass in the mid-season period. Further increases in the mid-season supply are undesirable due to the costs associated in controlling grass quality during this period. As the grazing season progresses both the supply of grass and the demand for it fluctuate, resulting in changes in the economic value of grass (Doyle and Elliott 1983).

Grass silage is the principal source of winter feed for livestock in Ireland (Drennan, Carson and Crosse 2005) where 87% of farms harvest silage annually, from 1 Mha (CSO 2010). The average proportions of this total area harvested for 1st and 2nd cut silage are 0.78 and 0.21, respectively (O'Donovan *et al*. 2010). This emphasises the importance of 1st and 2nd cut silage in Irish production systems. There is a growing tendency, on Irish dairy farms, to conserve silage from a block separate to the main grazing area and this practice is likely to become more common as stocking density increases. This creates a requirement for an economic value solely based on silage DM yield; in this scenario

Table 7. Individual performance[a] of 20 perennial ryegrass cultivars for dry matter (DM) yield, silage DM yield and herbage DM digestibility (DMD)

Cultivar	DM yield (kg/ha)			Silage DM yield (kg/ha)		DMD (g/kg DM)					
	Spring	Mid-season	Autumn	1st Cut	2nd Cut	Apr	May	Jun	Jul	Aug	Sep
1	1430	7686	3642	5323	2960	851	825	796	829	816	807
2	1662	7355	3531	5349	2701	849	813	803	834	809	790
3	2126	6835	3277	4994	3090	849	829	779	798	793	775
4	2283	7047	3176	5214	3334	832	830	782	789	801	791
5	2158	7342	3512	4727	3039	852	835	796	807	808	807
6	1213	6811	3177	4944	3004	847	811	790	812	797	780
7	1680	6950	3528	4702	3308	852	843	795	815	813	813
8	1891	7227	3245	5278	3637	856	838	793	794	805	825
9	1546	7125	3432	5964	2470	845	816	794	818	808	798
10	1374	7355	3445	5606	3240	845	815	801	819	803	806
11	1797	7025	3207	5027	3516	852	832	788	797	805	805
12	1827	6823	3334	5228	3527	857	841	803	812	803	813
13	1703	6966	3127	5795	3243	847	833	787	814	805	811
14	1857	6828	3233	5375	3032	845	830	783	810	803	799
15	1392	6912	3453	5181	3017	840	815	791	817	797	790
16	1453	7637	3474	4521	2873	844	816	793	814	797	789
17	1691	6939	3307	5002	3356	852	841	792	812	816	856
18	1667	6861	3190	4921	3192	844	834	784	807	762	801
19	1371	7066	3407	5235	2942	845	809	794	813	797	786
20	1971	7339	3495	5131	3057	854	839	779	804	797	771

[a] Data for spring, mid-season and autumn DM yield and all quality data are from simulated grazing management; data for 1st and 2nd cut silage yield are from the 2-cut silage management protocol.

the economic value of an increase in silage DM yield is much higher than that associated with the economic value applicable under the base scenario.

The nutritive value of perennial ryegrass varies throughout the growing season (Walsh and Birrell 1987; Johnston, Singh and Clarke 1993). In the current study DMD was highest in April (848 g/kg) and declined until June (791 g/kg), before increasing slightly for July (811 g/kg) and remaining relatively stable until September. An increase in the proportion of stem as the plant changes from a vegetative to reproductive growth phase (May to June period) is associated with a decline in plant digestibility. Differences in DMD amongst cultivars of temperate grasses tend to be greatest in mid to late summer, when the digestibility of fibre is at its lowest (Wilkins 1997). This is similar to the findings from the current study. The standard deviation of DMD between cultivars was 6, 11, 7, 11, 11 and 19 g/kg in the months of April to September, respectively, indicating that the differences between cultivars tended to increase as the season progressed.

High persistency is desirable as full cultivation and reseeding is expensive (Wilkins and Humphreys 2003). Shalloo, Creighton and O'Donovan (2011) indicated that if the rate of decline in sward persistency increased from 2% to 5% per annum there was a substantial reduction in the farm profitability. Additionally, poor persistency may have an environmental cost as less persistent cultivars must be replaced more frequently. Within the economic index, persistency has the potential to have a large impact on the overall ranking of cultivars.

Table 8. Economic value (€/ha) for yield traits and digestibility based on performance data for each cultivar, and total economic value of each cultivar

Cultivar	Component value					Total value
	Spring yield	Mid-season yield	Autumn yield	Digestibility	Silage yield	
Cultivar 1	–41.72	17.37	29.13	42.0	1.0	47.83
Cultivar 2	–6.53	7.47	17.68	25.3	–4.1	39.85
Cultivar 3	64.10	–8.15	–8.53	–54.0	–6.9	–13.43
Cultivar 4	87.95	–1.78	–18.88	–41.0	6.0	32.32
Cultivar 5	68.96	7.06	15.67	20.7	–16.8	95.60
Cultivar 6	–74.78	–8.87	–18.84	–35.7	–10.5	–148.63
Cultivar 7	–3.74	–4.70	17.36	44.5	–11.5	41.94
Cultivar 8	28.35	3.62	–11.82	16.5	15.1	51.71
Cultivar 9	–24.14	0.56	7.44	4.1	10.9	–1.20
Cultivar 10	–50.25	7.47	8.81	13.2	16.8	–3.96
Cultivar 11	14.09	–2.43	–15.75	–5.6	4.0	–5.70
Cultivar 12	18.57	–8.51	–2.68	39.0	10.9	57.30
Cultivar 13	–0.20	–4.22	–23.94	15.1	23.1	9.91
Cultivar 14	23.21	–8.35	–13.01	–8.3	4.4	–2.04
Cultivar 15	–47.50	–5.84	9.62	–18.0	–2.4	–64.08
Cultivar 16	–38.30	15.92	11.76	–19.5	–27.5	–57.61
Cultivar 17	–2.12	–5.03	–5.37	69.0	–0.5	55.98
Cultivar 18	–5.65	–7.37	–17.45	–44.5	–6.9	–81.87
Cultivar 19	–50.78	–1.22	4.87	–26.0	–2.3	–75.43
Cultivar 20	40.47	6.98	13.93	–36.8	–3.1	21.52

Economic value

Changes in grass supply and herd demand influence the economic value of grass across the season. In the spring and autumn periods the demand of the herd generally exceeds the supply of herbage on the farm. The extent and duration of this feed shortage is influenced by stocking rate, calving date and weather conditions, which influence grass growth. This resulted in a much higher value for extra DM yield during the spring and autumn periods (0.15 and 0.10 €/kg DM) compared to the mid-season value (0.03 €/kg DM). Doyle and Elliott (1983) also reported a change in the value of grass according to production season. In Ireland, grass supply generally exceeds herd demand during the mid-season period, hence the small benefit from extra grass in the system during this period. Currently, an objective within many plant breeding programmes is to increase the seasonal DM production of cultivars and so provide a more even distribution of yield across the year (Casler and van Santen 2010). Cultivars that express higher seasonal production will achieve a high value within the economic index due to the relatively higher value of spring and autumn DM yield, and therefore will increase the potential to improve the profitability of the farming system. In Southern Australia, Chapman, Kenny and Lane (2011) reported that in spring there is generally a surplus of pasture relative to herd demand, therefore additional feed grown would need to be conserved, while a feed deficit generally occurs during the summer period; in such a scenario, the economic value of summer DM yield is likely to be higher than the value of spring or autumn yield.

The fluctuation in economic value for DMD over the period April to September reflects the effect of a change in FV of the forage and the resulting effect on voluntary dry matter intake, which is dependant on the intake capacity of the animal (Dulphy, Faverdin and Jarrige 1989). Casler (2000) reported that *in vitro* DMD is the best single indicator of the nutritional value of a wide range of forage species for ruminants. The difference in total economic value for quality between the best and worst grass cultivars was €123/ha [range –€54 (Cultivar 3) to +€69 (Cultivar 17)]. This variation in DMD between cultivars highlights the requirement for frequent sampling of DMD within evaluation protocols to ensure that differences between cultivars are detected. Differences between cultivars in morphological and nutritive composition can have a significant effect on animal performance (Vipond *et al*. 1997; Gowen *et al*. 2003; O'Donovan and Delaby 2005). This was evident in the current study from the effect of a change in DMD on milk output within the MDSM. The range in DMD between cultivars had a significant effect on the economic performance of individual cultivars.

Within the current study, the economic value for persistency was calculated as –€4.96 per one percentage point decline per year. Due to insufficient data on the persistency of the cultivars in the plot study, persistency was excluded from the calculation of the total economic merit. It is likely that if persistency was included there would be a significant change in the rank of the cultivars for total merit index. For this reason, caution is advised when discussing the individual cultivars in terms of their total economic merit. The level of persistency will influence herbage production and also the decision on when to reseed. Although there is a large cost associated with reseeding swards, a rapid benefit can be obtained from the new pasture, in terms of increased sward quality and higher DM yield. Thus, Shalloo, Creighton and O'Donovan (2011) reported that reseeding 5% compared to 1% of a farm annually increased farm profit by €100/ha.

The scenarios involving a change in the utilisation of herbage did result in a change in the economic value. However, as the level of change in utilisation was similar across the spring, mid-season and autumn periods, the results indicated that regardless of the herbage utilisation level, there was no re-ranking of the cultivars. This indicates that assuming the relative differences in utilisation rate between the spring, mid-season and autumn periods are similar there will be no change in the ranking of cultivars if utilisation of the herbage fluctuates between farms. Brereton (1995) reported that average annual DM yield in Ireland ranges from 11 to 15 t/ha. The rank correlation between the scenarios differing in total DM yield (11 t/ha *vs*. 13 t/ha) was high indicating that where DM yield is lower or where farms are being operated less intensively the same cultivars are relevant.

The silage-only index is applicable to an intensive silage system. Evidence of re-ranking of cultivars in the plot study between the simulated grazing and the 2- or 3-cut silage management systems indicates that some cultivars are suited to grazing systems with others more suited to intensive silage systems. This was also evident when the economic values were applied to the data, as there was re-ranking of cultivars under the silage scenario (S4) compared to the base. As no other traits were considered important for this system the economic merit of cultivars in this scenario were entirely based on the yields of 1st and 2nd cut silage. The low correlation highlights the requirement for separate evaluation protocols for simulated grazing and intensive silage systems to identify the most suitable cultivars for both grazing and silage systems. This would provide the opportunity for farmers to choose cultivars suited to their particular system requirements.

Cultivar evaluation protocols

Perennial ryegrass has two distinct growth phases, reproductive and vegetative. Growth rate during the two phases is to a large extent genetically independent (Wilkins 1989). Reproductive growth accounts for a much larger proportion of the total annual DM yield under infrequent cutting (conservation systems) than it does under frequent cutting managements (simulated grazing systems); this can lead to genotype × cutting frequency interactions for total annual DM yield (Wilkins 1989). Results of the current study indicate that cultivars can be well adapted to either silage or grazing management, or both. However, some cultivars did rank differently for annual DM yield when managed for silage than when cut frequently to simulate actual grazing. Consequently, if only one management protocol was used to measure cultivar performance some cultivars could be incorrectly overlooked. This interaction underlines the need to ensure that the evaluation protocol represents the most common grazing practices within a particular country, which will then result in the best cultivars being identified for grazing systems.

Conclusions

There is potential to improve the profitability of pasture-based dairy system in Ireland, through the selection of cultivars with improved yield, quality and persistency. The economic merit index clearly identifies the strengths and weaknesses of individual cultivars, thus enabling farmers to select the most suitable cultivar to meet their individual requirements. Research and breeding programmes should focus on increasing the seasonal supply of grass, as currently the greatest feed deficits in a spring-calving system occur during these seasons, with the greatest economic benefit to increased grass availability occurring in the spring period. The evaluation protocol used must capture the traits of importance to ensure the accuracy of the index is maximised. The high correlation between the base scenario and scenarios involving a reduction in herbage utilisation indicate that regardless of intensity, the ranking of cultivars remains stable. The silage-only index will enable cultivars to be identified based on their suitability to an intensive silage system.

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